Jackson River Benthic TMDL Development

Endpoint Identification

TAC Meeting #3

Covington , Virginia

June 8, 2006

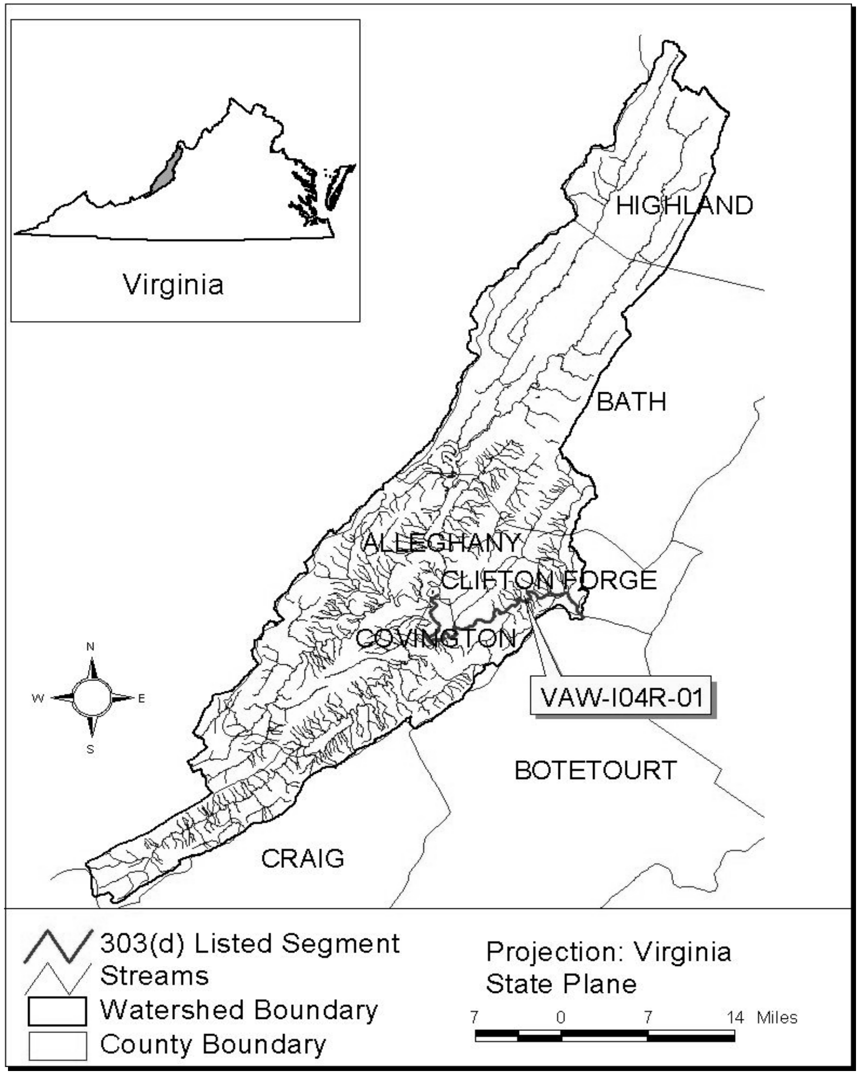
THE Louis Berger Group, INC.

Agenda

- **Recap the results from the Stressor Identification**
- **Present Nutrient and periphyton data**
- **Present Endpoint Determination Approach**
- **Develop TMDL Endpoint**
- **Describe Modeling Strategy**
- **Describe next steps**

Jackson River
Listed Segment

- **Segment VAW-I04R-01**
  - Listed on the 1996, 1998, 2002, 2004 Section 303(d) Lists of Impaired Waters (VADEQ)
- **Upstream Limit:**
  - Immediately below the Covington City Water Treatment Plant intake
  - 24.21 River Mile
- **Downstream Limit**
  - Confluence of the Jackson and Cowpasture Rivers
  - 00.00 River Mile



Benthic Impairment

- **Based on Biological Monitoring**
  - Assessments indicate the benthic community is impaired.
  - Therefore, the listed segment does not meet the Aquatic Life Use support goal.

The General Water Quality Standard: "All state waters shall be free from substances […] which are harmful to human, animal, plant or aquatic life." (9 VAC 25-260-20).

Stressor Identification

Stressor Identification

- **Each candidate stressor was evaluated based on available monitoring data, field observations, and consideration of potential sources in the watershed**

- **Potential stressors were further classified as a *non-stressor*, *possible stressor*, or *most probable stressor*.**

Stressor Identification

- **Biological Monitoring Data**
  - **EPA Rapid Bioassessment Protocols (RBPII)**
  - **Virginia Stream Condition Index (SCI) Scores**
  - **Habitat Assessment Scores**

- **Water Quality Monitoring**
  - **DEQ Instream Water Quality Data**
  - **MeadWestvaco Water Quality Data**
  - **Jackson River Periphyton Studies**

- **Discharge Monitoring Reports**

Stressor Identification Summary

Non-Stressors
Temperature and pH
Metals and Organics
Sediments
Wet Weather
Possible Stressors
TDS-Toxicity
Low Dissolved Oxygen
Flow Modification
Most Probable Stressors
Nutrients/Periphyton

Nutrients-Periphyton: Most Probable Stressors

- **Excess nutrients over-stimulate algal growth which alter macroinvertebrates communities by providing an increase in food supply for opportunistic invertebrates that use algae as a food source**

- **These opportunistic invertebrates can easily out-compete more sensitive species and dominate a community (EPA, 2000)**

Nutrients-Periphyton: Most Probable Stressors

- **Benthic macroinvertebrate community is affected by a change in instream habitat since the abundance of periphyton will cover the majority of instream habitat areas**

- **Excessive algal growth alters the natural balance in the benthic community and creates a shift toward pollution tolerant organisms that feed on algae (scrapers) and suspended detritus (collector-filterers)**

- **Overall, an increase in nutrients**
  - Will increase the periphyton biomass

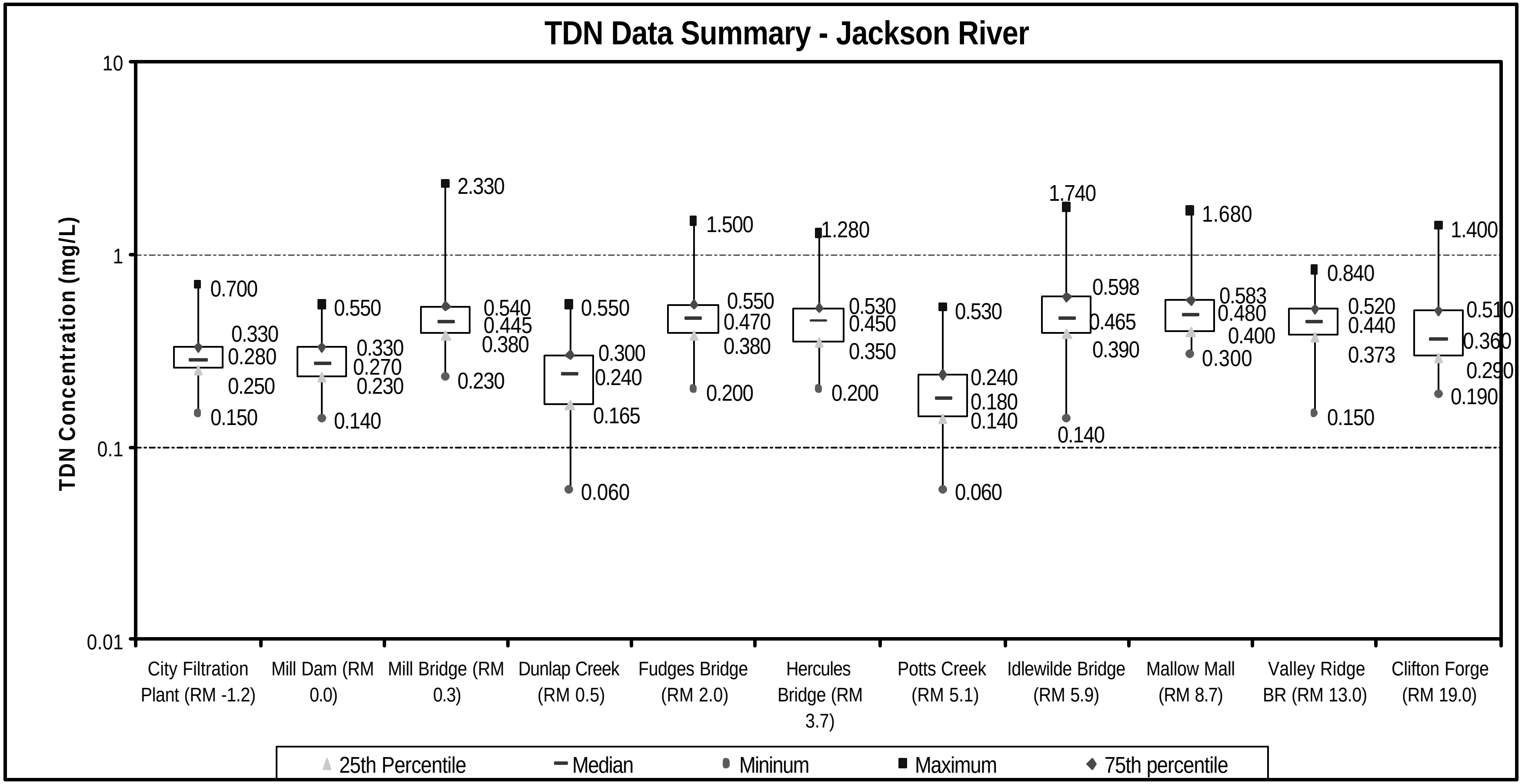
  - will lower the macroinvertebrate species diversity and reduce the variety of food available for fish and other vertebrates present within the ecosystem

Stressor Identification Summary

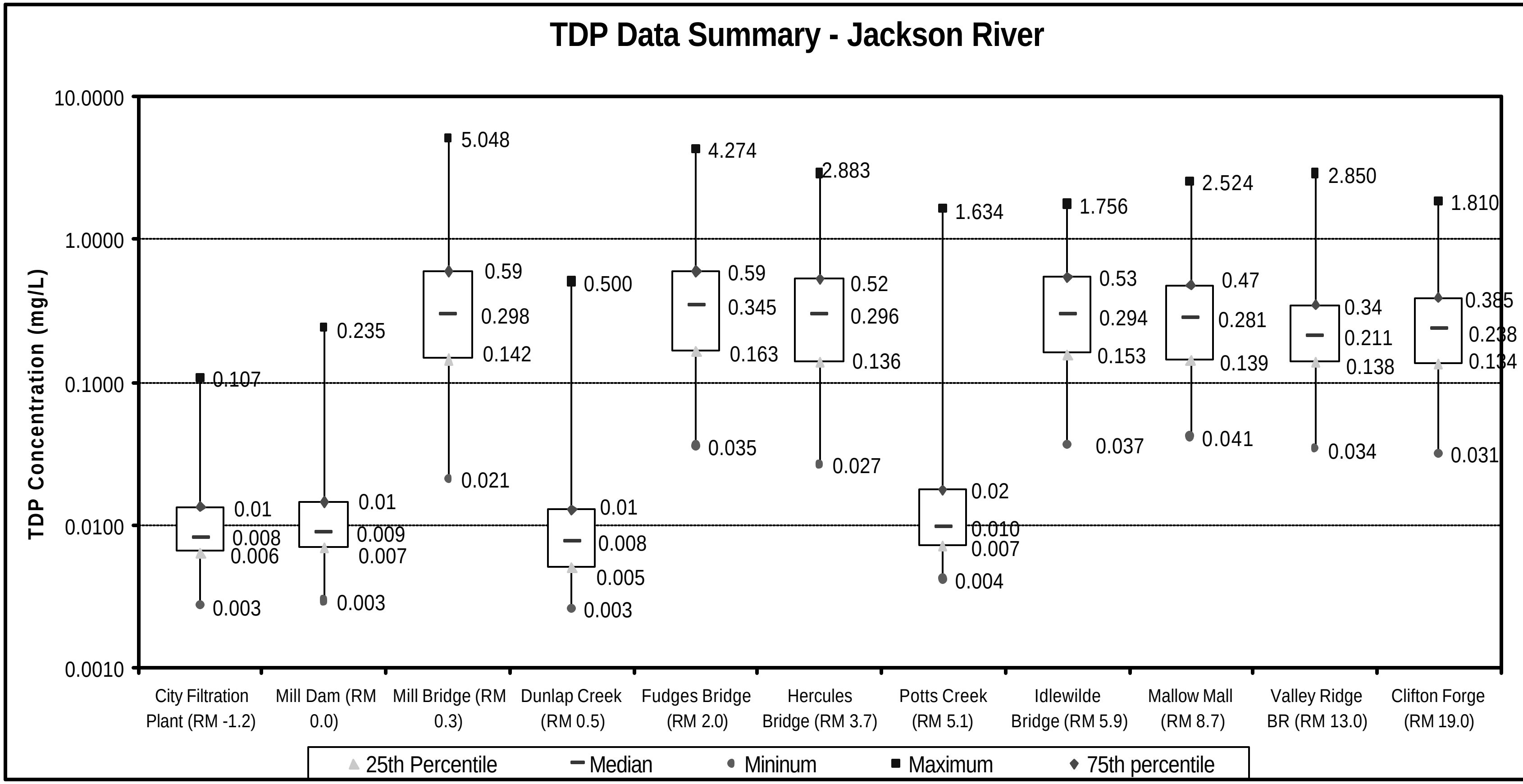
- **The common endpoint stressor is the excessive periphyton growth causing the benthic impairment**
- **This excessive periphyton growth is mainly causes by the excessive nutrients in the river**
- **Consequently, the periphyton issue in the Jackson River will be addressed through a reduction in nutrient loadings**

Nutrients and Periphyton Data

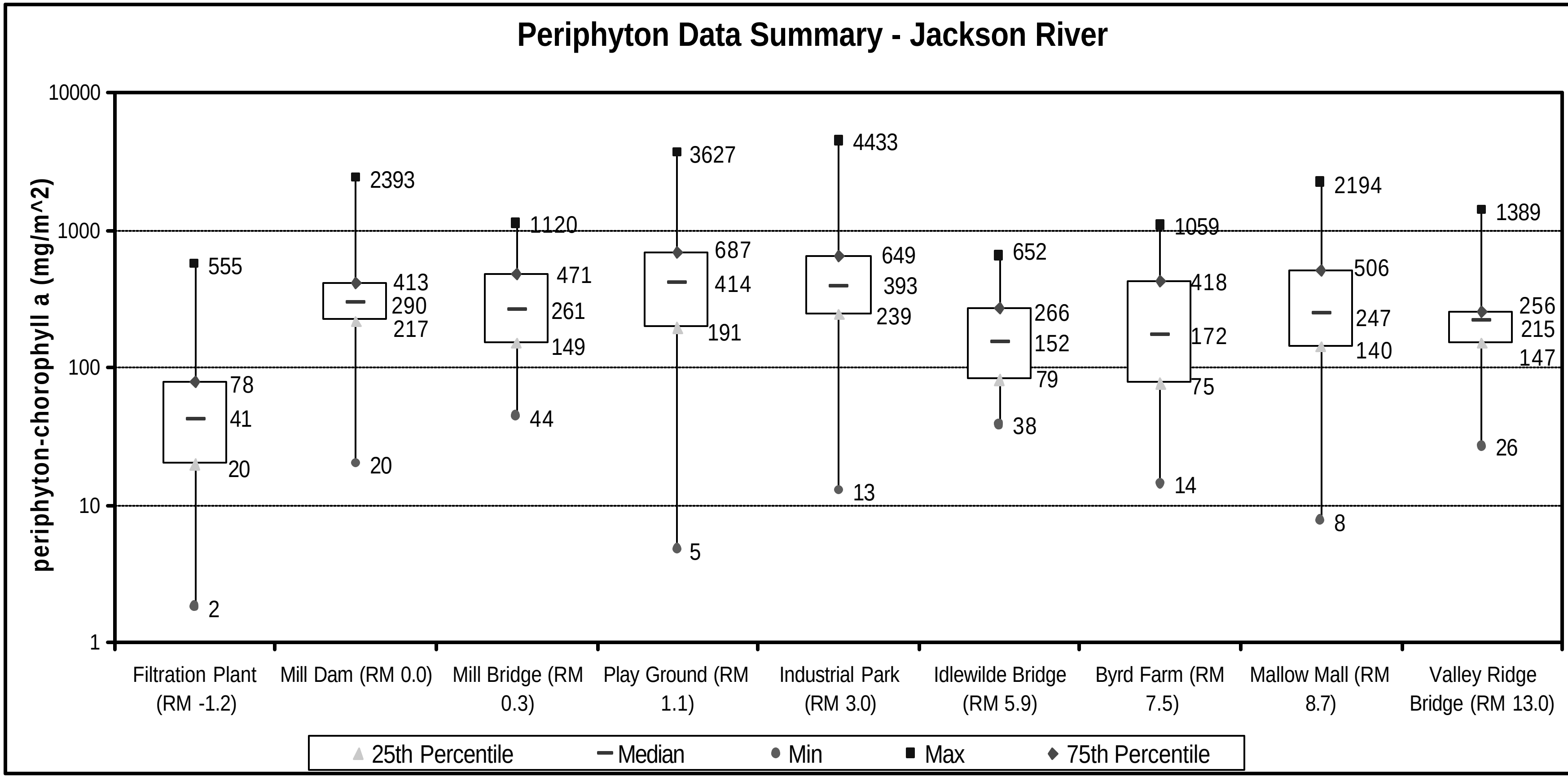
Analysis of Existing WQ Data: TDN



Analysis of Existing WQ Data: TDP



Analysis of Existing WQ Data: Periphyton



Endpoint Determination Approach

Endpoint Determination Approach

Identify acceptable Periphyton Benthic Chlorophyll *a* levels

Develop statistical relationships; establish correlations linking periphyton biomass and nutrients

Are there strong relationships between stream periphyton and nutrients in the Jackson River?

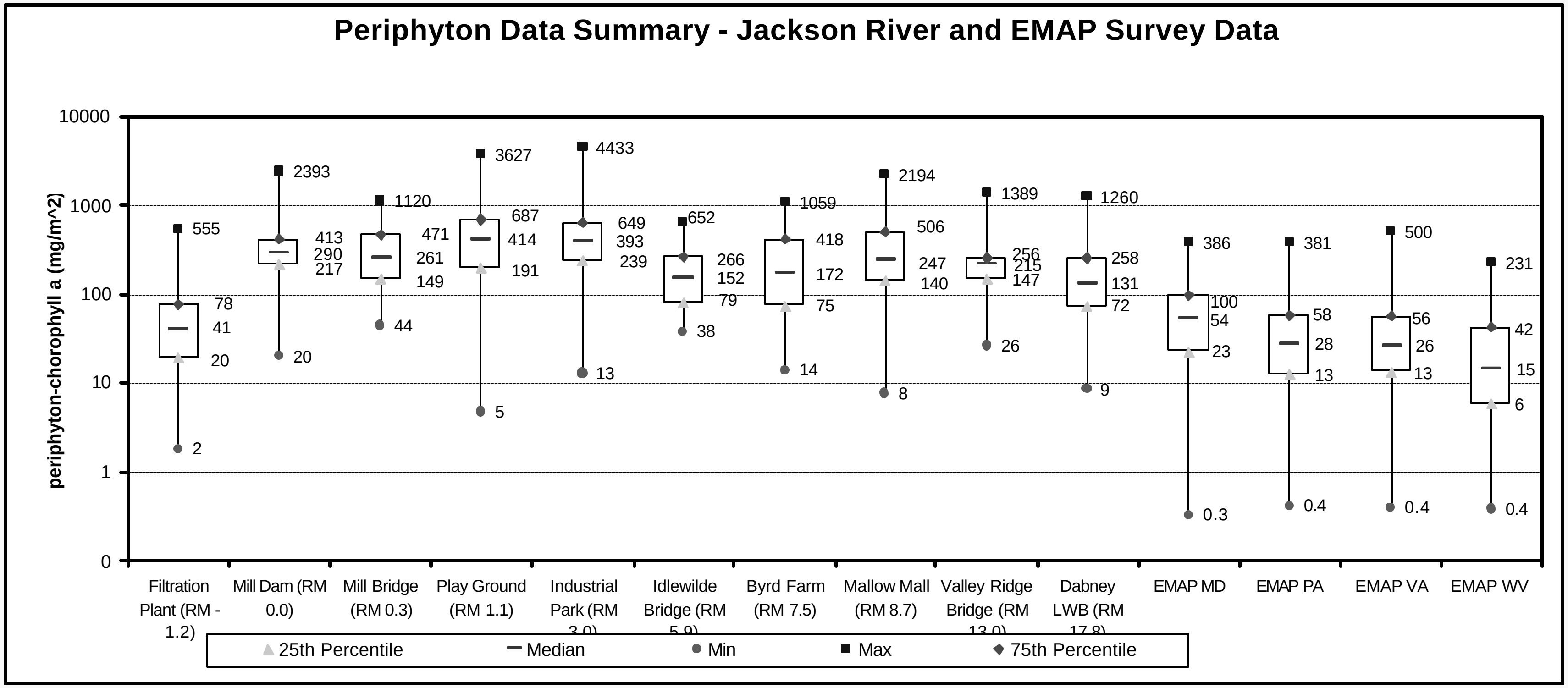
Use the derived relationship between periphyton and nutrient to develop the nutrient endpoint using the *acceptable level of periphyton*

Identifying the Acceptable Level of Periphyton

- **It is the level of periphyton that will not impair the benthic macroinvertebrate community?**

- **Approaches to identify this level of periphyton:**
  - **Reference watershed**
  - **Reference Station in the Jackson River**
  - **Literature/studies**

Identifying the Acceptable Level of Periphyton



- Identify reference value based on similar streams or ecoregion (e.g. EMAP Data)
- Most upstream station in the Jackson River (Filtration Plant) can be used as a reference (data shows that the benthic macroinvertebrate community is non-impaired 3 miles upstream of this station)
- Use accepted periphyton literature values which are not considered excessive and not at nuisance levels

Endpoint Determination Approach

- **Selected to use literature values:**
  - Based on previous work benthic chlorophyll levels in streams that range between 100-150 mg/m^2 are considered excessive and at nuisance level (Welch et al. 1988, EPA Nutrient Criteria 2000)
  - Consequently, benthic chlorophyll levels below or at 100 mg/m^2 are the periphyton TMDL endpoint in the Jackson River

Develop Statistical Relationships

Develop Statistical Relationships

- **Establish correlations linking periphyton biomass and nutrients**
- **Empirical regression models that link Phytoplankton and water column nutrients have been used successfully in the eutrophication management of freshwater lakes and reservoirs**
- **Only recently similar relationships analysis between periphyton and water-column nutrients were developed (Dodds et. al. 2002)**
- **Propose to develop relationships between periphyton and water-column nutrients specific to the Jackson River**

Develop Statistical Relationships

- **Extensive ambient monitoring exist in the Jackson River**

- **MeadWestvaco water quality and periphyton data and VADEQ's extensive monitoring program at different stations in the Jackson River**

- **The data include nutrient (N,P) and periphyton observations at several stations along mainstem the Jackson River**

- **The objective:**
  - Characterize the relationships between water-column nutrients and periphyton biomass in the Jackson River using regression methods

Develop Statistical Relationships

- **First, the complete data was screened to identify observations containing simultaneous TN, TP, and benthic chlorophyll (only data collected during the same day are included in the analysis).**

- **These water quality observations from all the stations were collected during the months of June trough October and were combined in one data set**

- **The statistical package Minitab**Ò **(Version 14) was used to develop these regressions**

Summary of Regression Results

Regression Models for Benthic Chlorophyll as a Function of nutrients in the Jackson River				
Dependent Variable (Response)	**Independent Variable 1**	**Independent Variable 2**	**Intercept**	**R-square**
Log Chla	0.400*Log(NH4)	-	2.63	0.093
Log Chla	-0.544*Log(NO3)	-	1.57	0.023
Log Chla	0.423*Log(PO4)	-	2.60	0.597
Log Chla	2.43*Log(TDN)	-	2.90	0.293
Log Chla	0.543*Log(TDP)	-	2.62	0.602
Log Chla	0.524*Log(TDP)	0.178*Log(TDN)	2.66	0.603

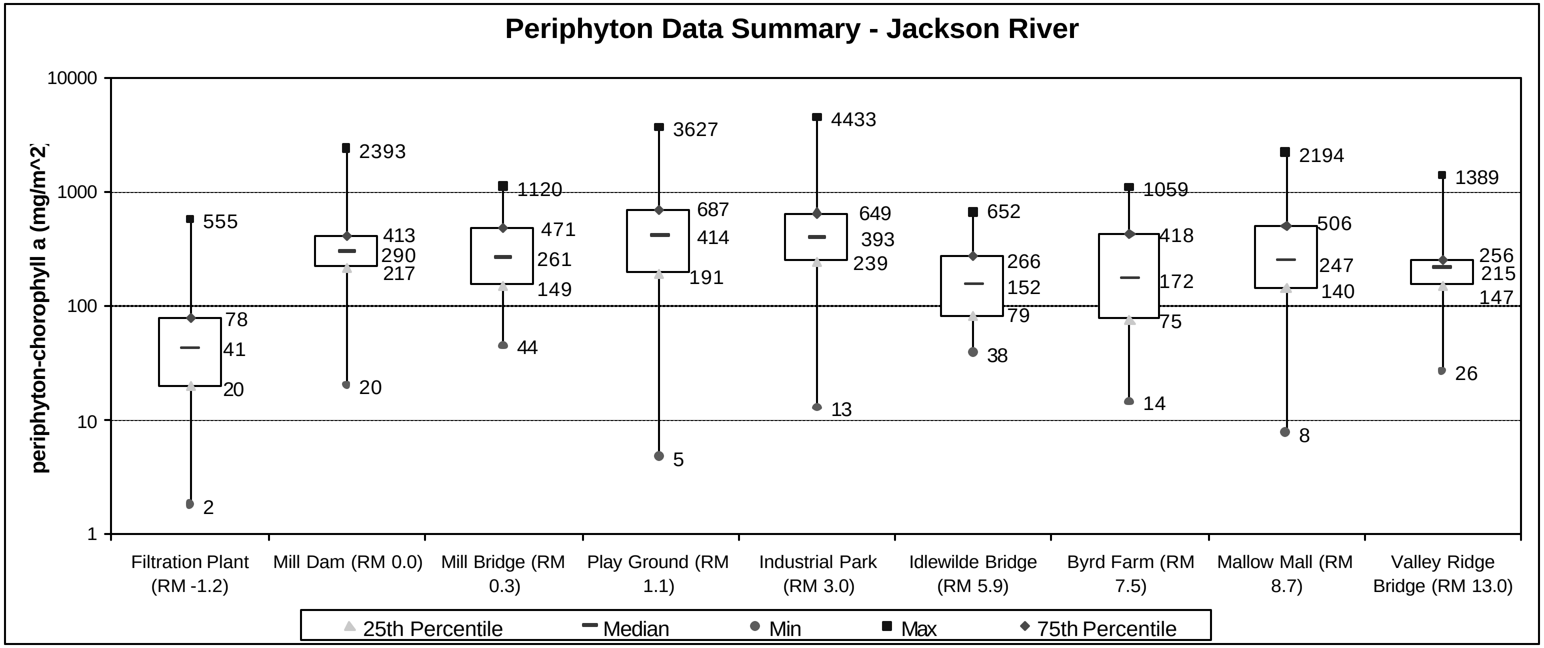
- **Phosphorus explains 60% of the periphyton variations**
- **Weak relationships were derived using the nitrogen species (NH4, NO3, and TDN)**
- **Using TDP and TDN as independent variables, the result shows a strong relationship, indicating that the TDN and TDP, when combined, explain approximately 60% of the benthic biomass variations in the Jackson River**

Variables Affecting Periphyton Growth

- Nutrients
- Flow (flooding)
- Light/shading
- Grazing

Question: Is the flow in the Jackson a dominant variable that will explain the excessive periphyton growth?

Streamflow and Periphyton Growth



- All these stations are under the same flow regime

- Upstream station in the Jackson (Filtration Plant) has low levels of periphyton

- Regression developed between streamflow and periphyton biomass shows weak relationship; with an R-square of 1.2 % (min 216 cfs, mean = 310 cfs)

Consequently, streamflow is not a major factor that can explain directly the excessive periphyton growth

Analyzing the Regressions

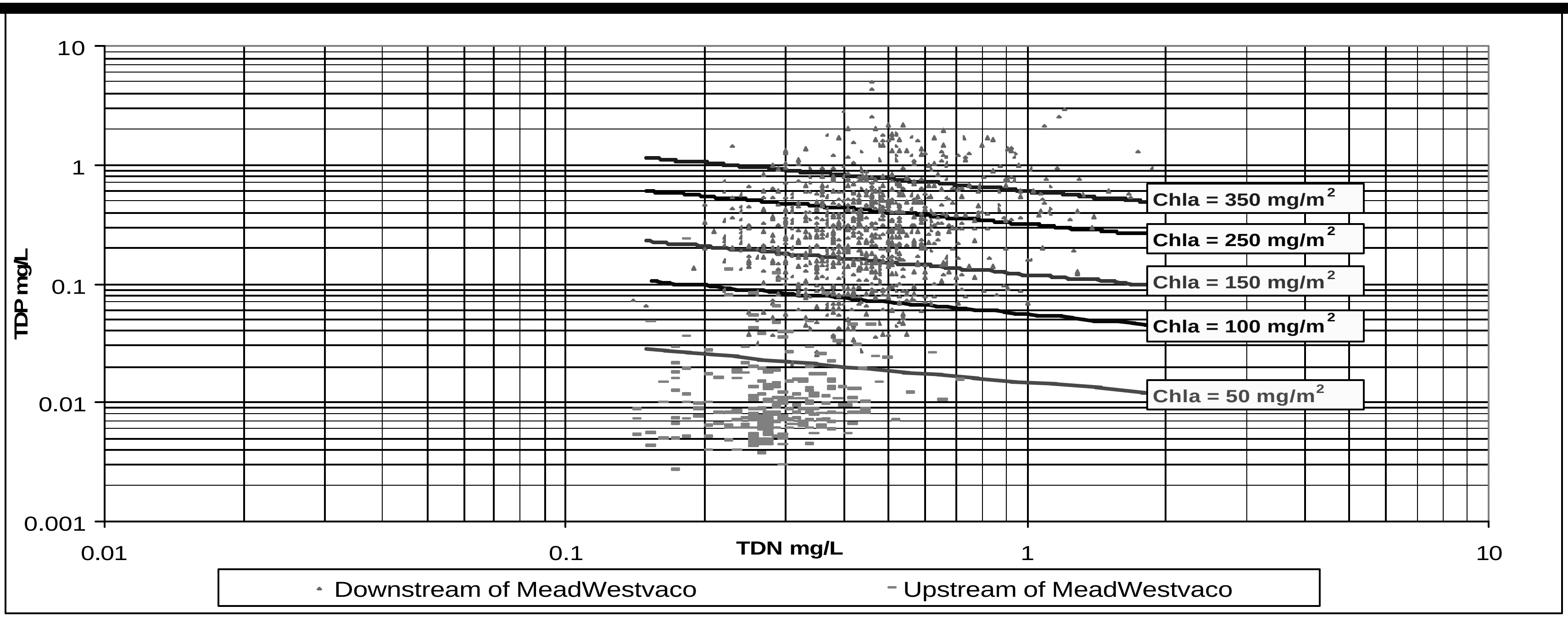
Response = Periphyton Chla **Independent Variables = TDN & TDP**

Log (Chla) = 0.524*Log (TDP) + 0.178*Log (TDN) + 2.66 ($r2$ = 0.603)

Response = Periphyton Chla **Independent Variable = TDP**

Log (Chla) = 0.543*Log (TDP) + 2.62 ($r2$ = 0.602)

Log (Chla) = 0.524*Log (TDP) + 0.178*Log (TDN) + 2.66 (r^2 = 0.603)



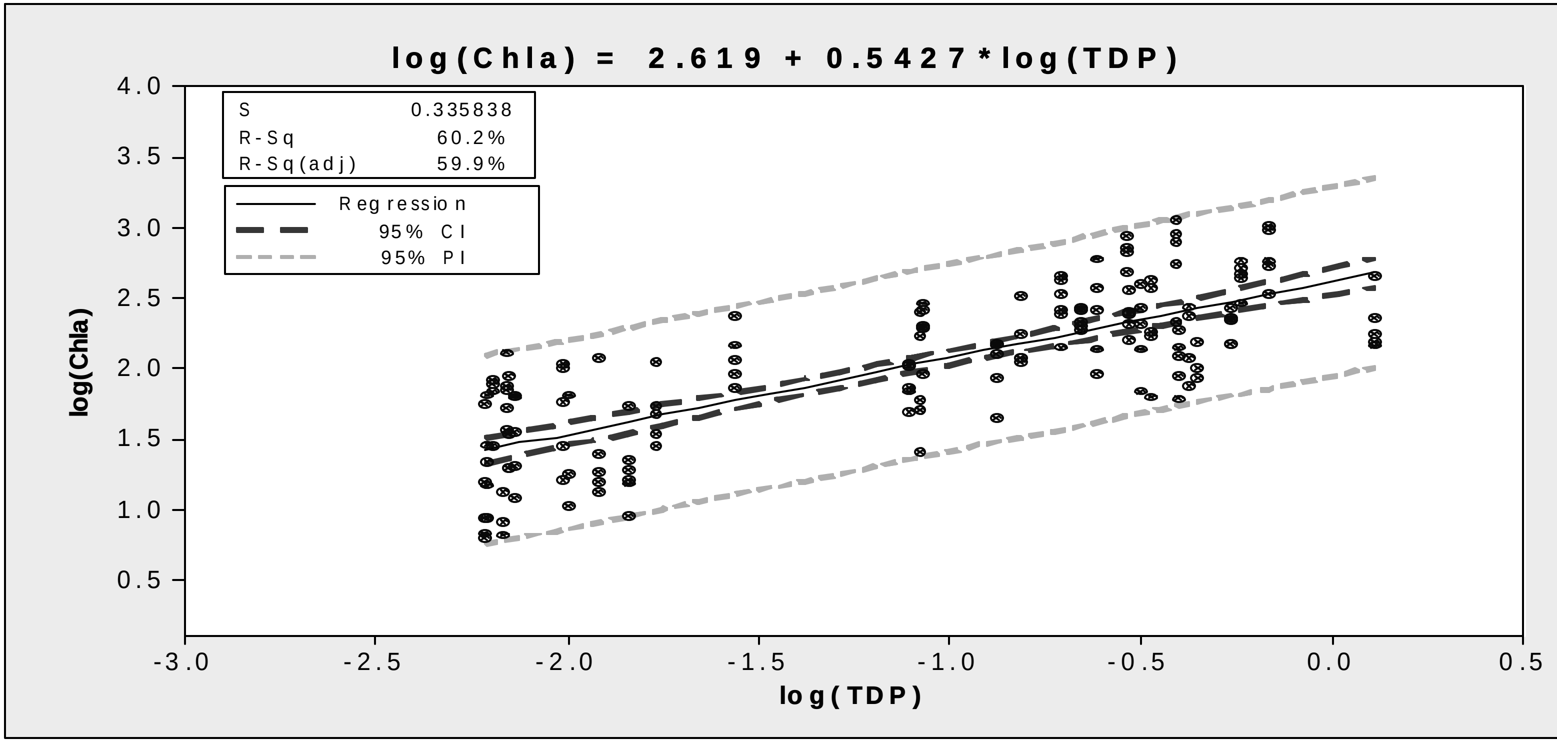
Multiple regression reproduces quite well the observed periphyton concentrations

Upstream of the MeadWestvaco discharge at the Filtration Plant Station, the average Chla concentration is approximately 58 mg/m^2 (green dots)

Most of the observations below the MeadWestvaco discharge fall between 200 and 350 mg/m^2, which reproduce quite well the observed periphyton data (blue dots)

Assuming that mean TDN level remains unchanged in the Jackson River and at 0.49 mg/L; TDP levels of <u>0.070 mg/L</u> are needed to achieve a periphyton concentration 100 mg/m^2 respectively.

Periphyton-Chla and TDP Relationship



- **Relationship results in an average TDP concentration of <u>0.072 mg/L</u> to achieve a periphyton concentration 100 mg/m2.**

- **This endpoint is similar to the one derived using the multiple relationship between Chla, TDP, and TDN.**

TDP TMDL Endpoint

Proposed Nutrient TMDL Endpoints and Resulting N:P ratios		
TDP TMDL end-point (mg/L)	Periphyton-Chla (mg/m^2)	N:P ratio
0.072	100	6.8
0.047	80	10.4

TMDL end-point for a 100 mg/m^2 shifts the Jackson River to a "borderline" phosphorus-limited system.

To ensure that the periphyton biomass will be reduced in the Jackson River, it is necessary to shift the system to a completely phosphorus-limited one by selecting a lower periphyton target than 100 mg/m^2.

A periphyton-chlorophyll concentration of 80 mg/m^2 corresponds to a TDP end-point of 0.047 mg/L and corresponds to an average N:P ratio of 10.4

Total Phosphorus TMDL Endpoint

- **We need to convert the TDP endpoint concentration to Total Phosphorus using an average ratio of 0.75 (TDP =75% of TP)**

- **Average ratio based on analysis of the Chesapeake Bay Modeling Results for the James River (personal communication, Modeling Group)**

- **Consequently, the TP endpoint in the Jackson River is approximately 0.063 mg/L (0.047/0.75)**

Comparison of Potential TP Endpoints

Comparison of Potential TP TMDL Endpoints	
Source	TP Endpoint (mg/L)
Chesapeake Bay 2010 Cap Allocations (minimum value)	0.065
VADEQ Reference Value (25^{th} percentile)	0.01
EPA Reference Value (25^{th} percentile)	0.01
Jackson River Regression	0.063

Modeling Strategy

- **Watershed Model**
  - Hydrologic Simulation FORTRAN (HSPF) to estimate nutrient NPS loads

- **Instream Model**
  - Water Analysis Simulation Program Version 7

Hydrologic Simulation Program Fortran (HSPF)

- **Hydrologic model**
- **Watershed model**
- **State of the art modeling system**
- **EPA approved approach**
- **Being implemented by the EPA Chesapeake Bay Program**

WASP7 Description

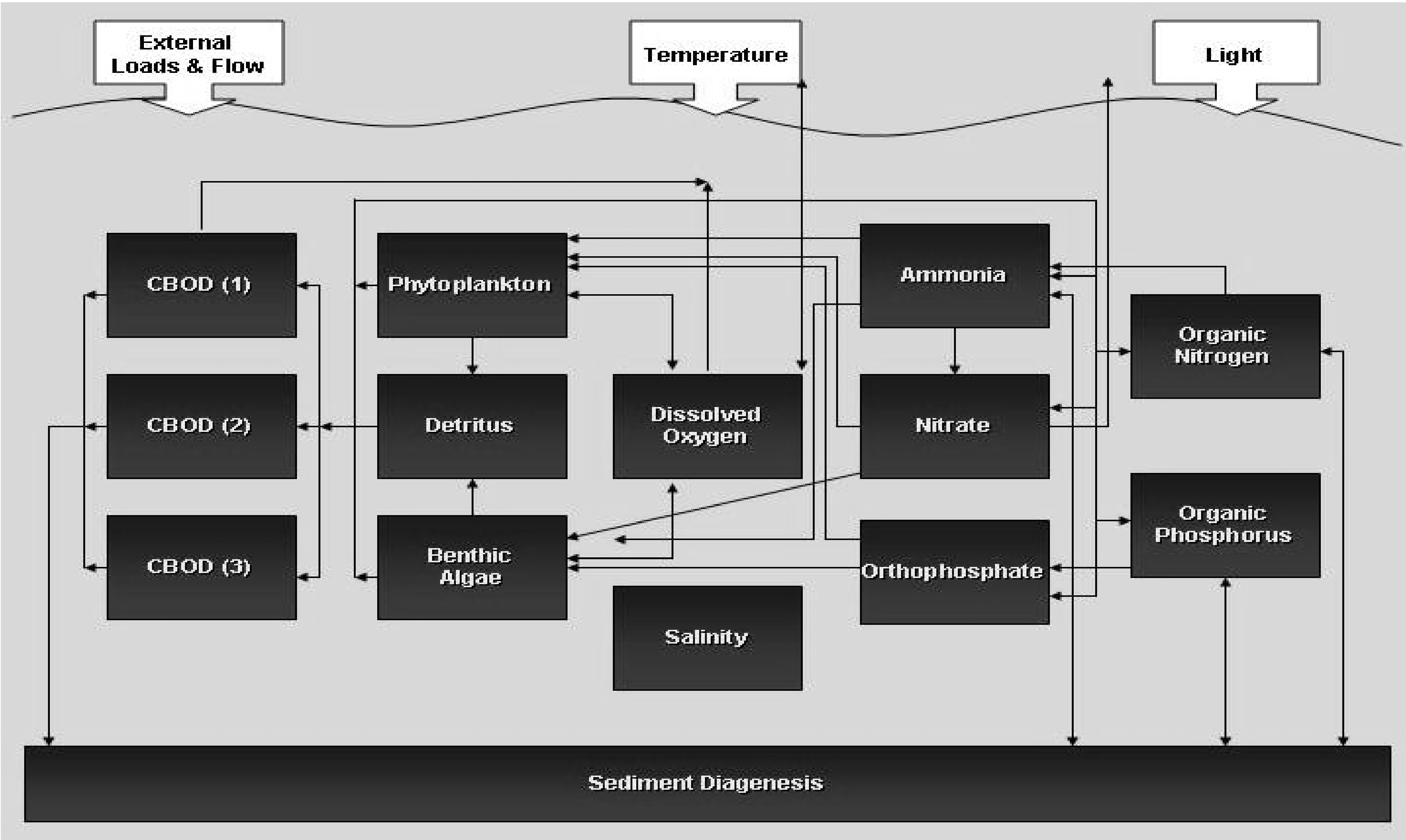
- **U.S. EPA generalized modeling framework that simulates contaminant fate in surface waters**
- **Based on the flexible compartment modeling approach, WASP7 can by applied in one, two, or three dimensions**
- **Problems that have been studied include biochemical oxygen demand, dissolved oxygen dynamics, nutrients, bacterial contamination and toxic chemical movement**

WASP7 State Variables

- **Ammonia**
- **Nitrate**
- **Orthophosphate**
- **Dissolved Oxygen**
- **Salinity**

- **Phytoplankton**
- **Periphyton**
- **Particulate Detritus**
  - Carbon
  - Nitrogen
  - Phosphorus
- **Dissolved Organic Matter**
  - CBOD (1)
  - CBOD (2)
  - CBOD (3)
  - DON
  - DOP

WASP7 Eutrophication Diagram



WASP7 MODELING

- Use the WASP7 model to simulate nutrient fate and periphyton growth
- Model driven by 15-min flows at Gathright, Dunlap Creek, and Potts Creek
- Estimate NPS contributions using the HSPF model (time series)
- Link NPS file to the WASP7 Model
- Calibrate and validate the model for the 2000 to 2002 period
- Develop scenarios; Develop WLAs and LA

Next Steps

- **Develop WASP7 existing condition scenario run (2000-2003)**
- **Develop time series NPS nutrient loads**
- **Link NPS loads to the WASP7 Model**
- **Calibrate and Validate the Model**
- **Develop Allocation Scenarios**
- **Develop WLAs and LAs**
- **Prepare Draft TMDL Report**

Local TMDL Contacts

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